

HAZARDS TO RAPTORS FROM STRYCHNINE POISONED GROUND SQUIRRELS

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ABSTRACT.—To evaluate the potential for secondary poisoning of raptors from poisoning campaigns for ground squirrels, we placed eviscerated, strychnine-poisoned Richardson's Ground Squirrels (*Spermophilus richardsonii*) into Swainson's Hawk (*Buteo swainsoni*) nests and monitored nestling survival. Of 52 nestlings which consumed 67 poisoned ground squirrels, 49 nestlings survived the treatment period. We could not detect a difference in growth rates between treated and control nestlings, nor a difference in survival after the treatment period. We present evidence to suggest that raptors eviscerate ground squirrels prior to consumption. This evisceration probably has a profound influence on the survival of raptors scavenging poisoned ground squirrels.

Use of poisons to control unwanted wildlife poses potential threats to predators and other non-target species (Mendenhall and Pank 1980; Townsend et al. 1981; Holler and Schafer 1982; Merson et al. 1984; Marsh et al. 1987; Hegdal and Colvin 1988). Strychnine, the active ingredient in several forms of ground squirrel poison (e.g., "Gopher Cop"® or "Strychnine Gopher-kill Liquid"®), is highly toxic to birds; LD₅₀s for most species tested ranged from 2–25 mg/kg (Hudson et al. 1984). Strychnine has been implicated in the mortality of several species of raptors (Reidinger and Crabtree 1974; Cromartie et al. 1975; Kaiser et al. 1980; Redig et al. 1982; Bortolotti 1984; Reichel et al. 1984). Strychnine is used throughout prairie Canada each year to poison Richardson's Ground Squirrels (*Spermophilus richardsonii*), and usage will probably continue until alternative, biological methods of control become available (e.g. Wodzicki 1973).

In this study we attempted to determine the potential threat to young hawks that are fed poisoned ground squirrels. Nestling hawks may be more subject to secondary poisoning because they, unlike adults (e.g., Brett et al. 1976), have less opportunity to reject poisoned prey. Cheney et al. (1987) found that even some adults did not learn to avoid strychnine-laced mice in captivity. We examined the survival and growth rate of nestling Swainson's Hawks (*Buteo swainsoni*) into whose nests we placed poisoned ground squirrels. We selected Swainson's Hawks for this study because >65% of their prey biomass was comprised of ground squirrels (Schmutz et al. 1980), and because Swainson's Hawks nested preferentially in cultivated areas (Schmutz 1987, 1989) where ground squirrels are poisoned. We also studied the frequency with which poisoned ground squirrels died above ground and were available to scav-

enging hawks. Rather than examining the effect of known amounts of poison on hawks, we simulated field conditions in an attempt to determine the magnitude of the threat under current poisoning practices.

STUDY AREA AND METHODS

This work was carried out adjacent to a study area near Hanna, Alberta (Schmutz et al. 1980). The area consisted of mixed-grass prairie in a semi-arid climate. The primary land use was grazing of cattle with 14% of the land under dry-land cultivation for cereal production.

To evaluate the potential impact of poisoning of ground squirrels on raptors, we offered poisoned ground squirrels to nestling Swainson's Hawks. Ground squirrels were captured locally using live traps (#102 and #103; Tomahawk Live Trap Co., Tomahawk, Wisconsin). Squirrels were held, one to a trap, in a ventilated room and offered water and approximately 200 g of poison-coated grain immediately after capture. "Strychnine Gopher-kill Liquid"® (Sanex Inc., Mississauga, Ontario; Registration No. 15849) containing 2% strychnine was used to coat oats according to the manufacturer's instructions. Up to 24 hr elapsed until some squirrels died, but most died within 12 hr. After a squirrel's death, we removed stomach, large intestine and small intestine, and marked the squirrel with two monel metal tags. One squirrel was deposited into a Swainson's Hawk nest (treated nest) on each of 3 consecutive d unless the nestlings had died. In the evening of the third day we visited the nests a second time to determine the fate of deposited prey and of nestlings. We chose a 3-d period assuming that this would approximate the period during which dead squirrels would be available to hawks during actual poisoning campaigns. All prey items found in treated nests were removed during daily visits. Prey items in control nests were not removed nor was prey added. These "control nests" did not represent a true control because of a net addition of food to treated nests. Sixty-nine ground squirrels were added to treated nests but only 23 prey items found were removed.

Nestlings were weighed during daily visits between 9–28 July 1988. To account for varying amounts of crop contents at the time of weighing, we subtracted 10% of a nestling's mass if the crop was judged full and propor-

tionately less if partially full. Age of nestlings at the start of the treatment period varied, as reflected in their body mass (J. K. Schmutz 1977). Mean age of 52 nestlings in "treated" nests was 13 d (range 2–26). Mean age of "control" nestlings was 16 d (range 3–25).

We compared reproductive performance among 3 groups of nests to examine the impact of poisoned food on nestlings. Twenty-five treated nests were selected just outside the eastern edge of a study area which was part of a long-term, ecological study of prairie raptors (e.g., Schmutz et al. 1980). Treated nests were interspersed with 13 "control nests." We assumed that the effect of poison on nestlings was independent of the amount of food available to them. We also compared the number of young fledged from treated nests with the success of a large sample of nesting pairs on the adjacent study area. To determine whether Swainson's Hawks actually scavenge dead squirrels, we placed 3 marked, unpoisoned ground squirrels within 30 m of each of 4 nests.

To examine whether placement of poison in or outside a burrow affected whether squirrels die above ground or below, we distributed poison on 9 plots of approximately 0.5 ha each. Poison was placed either inside the burrow (4 plots selected at random) or, contrary to the manufacturer's recommendation, atop a mound adjacent to a burrow entrance (5 plots). We returned the next day and recorded the number of dead ground squirrels outside a burrow. At this time, we plugged 25 burrow entrances with dry vegetation on each of 6 plots (3 plots with poison outside of burrows and 3 within). We recorded the number of plugged burrows that had been opened the following day and compared these proportions in relation to where poison was placed (atop or inside a burrow). We used burrows in the center of a poisoned area to minimize counting dispersing squirrels using the plugged burrows.

RESULTS

Observations of Raptor Feeding Behavior.

Swainson's Hawks and other raptors may be subject to secondary poisoning if they scavenge dead or take dying squirrels. We did not visit those nests where ground squirrels were placed on the ground frequently enough to document the fate of all squirrels. One marked squirrel was taken to the nest by a Swainson's Hawk. All other marked squirrels had disappeared. On 5 other occasions we have observed Swainson's Hawks attempt to or actually retrieve road-killed Richardson's Ground Squirrels. In addition, 2 crushed ground squirrels, evidently road killed, were found in nests during a study of food habits (Schmutz et al. 1980).

The impact of secondary poisoning on raptors could be much reduced if raptors rejected viscera. Some of our ground squirrels died only hrs after the consumption of poisoned bait, presumably after sufficient poison had been absorbed into the blood stream. Excess poisoned grain was contained in the

squirrels' stomachs. We removed stomach, and large and small intestine as the hawks did. Of 91 whole ground squirrels found in Ferruginous Hawk (*B. regalis*) nests and of 20 in Swainson's Hawk nests, 64 (70%) and 11 (55%) respectively had been eviscerated. Our additional observations of raptors indicate that the viscera are actually rejected. We observed a Northern Harrier (*Circus cyaneus*), a Ferruginous Hawk and 2 Swainson's Hawks kill ground squirrels, pull out the viscera in 2–3 strokes and drop the viscera onto the ground. The Ferruginous Hawk subsequently offered the ground squirrel to nearby fledglings without feeding itself. In 7 additional cases we observed a Northern Harrier, a fledgling Ferruginous Hawk, a Red-tailed Hawk (*B. jamaicensis*), and 4 Swainson's Hawks (1 fledgling) eat a duck, 5 ground squirrels or a mouse, with viscera lying on the ground within 1 m of the carcass. A captive Great Horned Owl (*Bubo virginianus*) rejected viscera when the entire ground squirrel was offered as food. We found mouse viscera discarded at the entrances into the nests of Burrowing Owls (*Athene cunicularia*) at least 8 times. The rejection of viscera may be related to prey size relative to raptor size because we observed a Short-eared Owl (*Asio flammeus*) swallowing viscera of a mouse consumed in pieces. In 29 cases we were able to examine portions of viscera that were found on the ground at kill sites or had been removed from squirrels found otherwise whole in nests (Fig. 1). In these cases the liver was attached to other rejected parts and may have been discarded accidentally.

Of 69 poisoned squirrels placed into treated nests, 6 were seen partially consumed 8–24 hr later. Sixty squirrels had disappeared from the nests and presumably had been consumed. Three squirrels were uneaten. We believe that all poisoned ground squirrels offered to surviving nestlings (67 squirrels) were eaten. In a previous study in which food was supplemented (Schmutz et al. 1980), excess food was reluctantly discarded by the parents if at all. Food began to rot and later dry up in the nests.

Hawk Survival. No adult mortality was evident in this study. Two adults were seen after the treatment period at all nests. We examined the potential impact of poisoning on nestlings in 3 ways, by (1) recording survival during the 3 treatment days, (2) monitoring survival after the treatment period, and (3) by comparing growth. Three of a total of 58 nestlings may have died from secondary poisoning. Three poisoned ground squirrels had disappeared

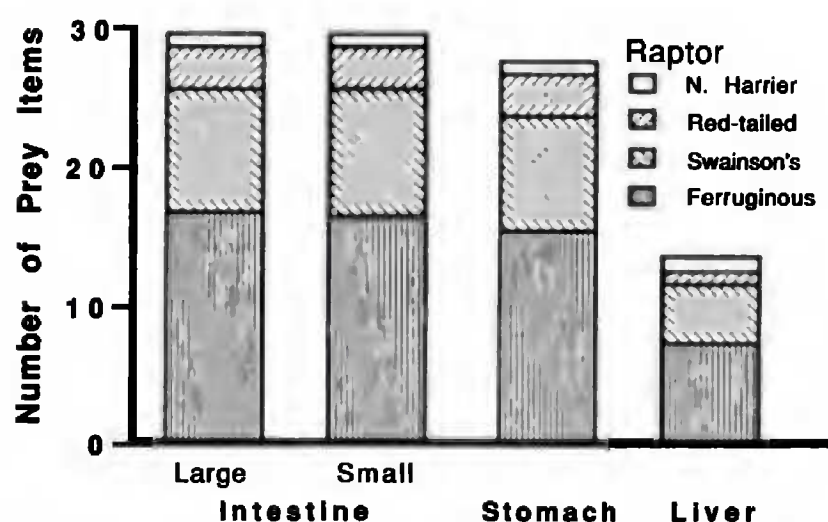


Figure 1. Portions of the gastrointestinal tract removed by various raptors from a duck, a vole, a songbird and 26 Richardson's Ground Squirrels.

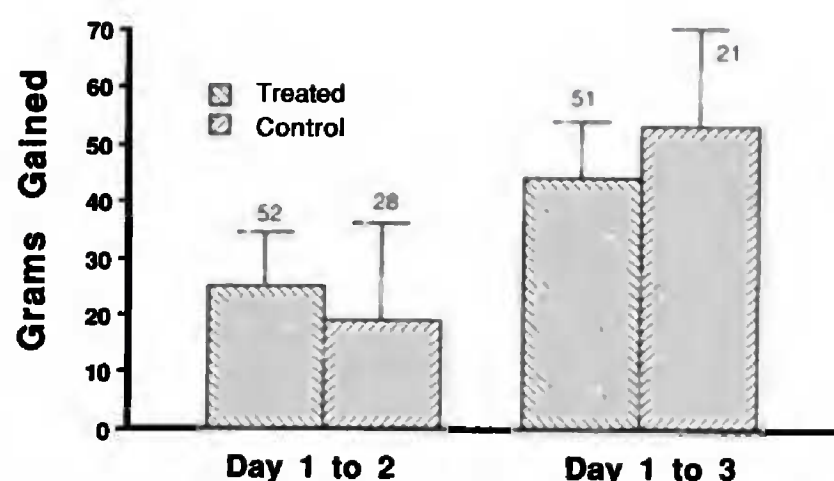


Figure 2. Growth of control and treated nestling Swainson's hawks which were fed strychnine-poisoned Richardson's ground squirrels over a three day period in southeastern Alberta. Lines represent standard error and numbers = sample size. Seven nestlings in control nests were not weighed on day 3 due to time constraints.

in these nests and had presumably been consumed. One partially eaten squirrel remained. An additional six nestlings died in 2 nests between the first and second visits before actually consuming any of the poisoned ground squirrels. These 2 nests were hence excluded from further analysis. Three of these 6 nestlings were partially consumed, suggesting predation as a possible cause of death. None of 28 nestlings in control nests died during this 3-d period. There was no significant difference in the survival between 52 treated and 28 control nestlings during the treatment period ($\chi^2 = 1.68$, $P = 0.195$).

All nests were visited a final time for banding. At this time no differences in brood size could be detected. Of the 52 nestlings in treated nests, 42 (72%) survived from the conclusion of the treatment period to the time of banding, an average of 12 d later (range 5–21 d). In control nests 23 of 28 (82%) nestlings survived to banding, an average of 10 d later (range 3–20; $\chi^2 = 0.97$, $P = 0.325$). Successful, treated pairs raised an average of 2.0, as did successful pairs which were not part of this study on the adjacent study area. Successful control pairs raised an average of 1.8 young.

Nestling Body Mass. Average mass of treated and control nestlings increased throughout the period (Fig. 2). On the third day, at the end of the treatment period, there was no significant difference in the mass gained by treated nestlings compared to controls (Mann-Whitney $U = 451$, $P = 0.794$).

Poison Placement. Potential for scavenging by raptors was not reduced by placing poison inside ground squirrel burrows. Eighteen squirrels were found at 606 burrows (3.0/100 burrows) at which poison was placed outside compared to 19 squirrels

near 434 burrows (4.4/100 burrows) where poison was placed within. Whether poison was placed outside or inside the burrow also had no significant influence on squirrel survival based on the frequency with which plugged burrows were opened. Thirty-two of 75 burrows with poison placed above ground were opened a day later, compared to 30 of 75 burrows with poison placed below ground ($\chi^2 = 0.11$, $P = 0.740$).

DISCUSSION

Absence of a clear indication of reduced survival due to secondary poisoning among treated nestling Swainson's Hawks was unexpected. There was also no evidence that nestling growth was affected by the treatment. If local environmental conditions had any bearing on the outcome of this study, the drought conditions of 1988 may have worsened the impact. We attempted to simulate actual field conditions and conclude that under those conditions, secondary poisoning through ground squirrels is a minor threat for Swainson's Hawks. Other buteonine hawks may be similarly unaffected since it is unlikely that Swainson's Hawks are unique with regard to the threat of secondary poisoning.

We could not control some variables in this field study. Our daily visits may have had a detrimental impact (e.g., White and Thurow 1985). We also did not know how much "clean" food was brought to nestlings by their parents, a factor which may similarly lessen the impact of actual poisoning campaigns.

Population performance of pairs of Ferruginous and Swainson's Hawks monitored during the last 13 years is consistent with a minor (if any) impact from secondary poisoning in the area. In 1986 strychnine use (1782 l of "Gopher Cop" in the Hanna area alone) was greater than during any other year in the last decade (Schmutz and Hungle 1989). Landowners distributed more poison in response to an increase in ground squirrel abundance. Nesting densities on the study area of both species were also higher in 1986 than during the preceding 10 yrs. Brood size among Ferruginous Hawks was greater in 1986 than during years of low strychnine use, while brood size of Swainson's hawks remained unchanged. Hegdal and Gatz (1977) also could not detect a detriment to raptors arising from ground squirrel poisoning. Some mortalities did occur but could not be attributed to the poisoning. Two Great Horned Owls monitored using radiotelemetry in their study, frequented the treatment area and were alive 4 mo after treatment.

Evisceration of poisoned ground squirrels is without doubt an important factor affecting the hazard to raptors. However, even eviscerated squirrels sometimes contained poisoned bait in their cheek pouches which could pose a threat. Our conclusion of a minor impact on raptors presupposes that the gastrointestinal tract of poisoned ground squirrels is not eaten. As soon as strychnine is absorbed into the blood stream, death probably occurs quickly, allowing relatively little strychnine to be present in the flesh. Raptors under food stress, however, may devour parts or all of a poisoned gastrointestinal tract and die.

Evisceration of prey prior to consumption is not unique to the raptors studied. Vatev (1987) found an eviscerated vole in a nest of Long-legged Buzzard (*B. rufinus*) in Bulgaria. Poole and Boag (1988) found that Gyrfalcon (*Falco rusticolus*) in Canada's north eviscerated Rock Ptarmigan (*Lagopus mutus*) and Arctic Ground Squirrel (*Spermophilus parryi*). Falcons frequently left the stomach and intestines of large prey on the nest site but ate small passerines and microtines entirely.

Mammalian predators which may eat ground squirrel viscera face a greater danger from secondary poisoning than do hawks. Marsh et al. (1987) found, however, that Coyotes (*Canis latrans*) rejected viscera from strychnine-poisoned ground squirrels 66% of the time. One coyote died in their study. On our study area, one landowner's dog died after eating

ground squirrels from a poisoned area. The potential threat to livestock arising from poison-coated grain is well recognized by landowners.

Efforts to estimate the potential impact from secondary poisoning to wildlife assume that poison users adhere to recommended procedure. Regulatory measures to protect wildlife may have little effect if not widely adhered to. Some landowners canvassed by us deliberately used more than the recommended dose in preparing bait; others used less. The prevailing practice was to spread poison in a given area once and to repeat poisoning 10–14 d later, depending on the degree of Richardson's Ground Squirrel survival and immigration. In some cases poisoned bait was placed inside a tire which resulted in persistent exposure to squirrels and thus to raptors. The influence of these deviations from recommended practice on secondary threats to wildlife is not known.

Because of their characteristic dispersal tendencies, especially by juveniles in July, squirrel populations are resilient to periodic, local eradication (Schmutz et al. 1979). Even adults removed in May–June repopulated a 4 ha plot to near former levels in <1 month (S. M. Schmutz 1977). From our experience, many landowners would attempt to ameliorate secondary impacts if made aware of the threat to non-target wildlife. Granivorous birds apparently face a greater threat from ground squirrel poisoning than do raptors. In a study in south-central Wyoming Hegdal and Gatz (1977) detected strychnine residues in the gastrointestinal tract of dead birds found in the area where poison had been broadcast. Casualty species included Mallard (*Anas platyrhynchos*), Mourning Dove (*Zenaida macroura*), Horned Lark (*Eremophila alpestris*), American Crow (*Corvus brachyrhynchos*), European Starling (*Sturnus vulgaris*), Yellow-headed (*Xanthocephalus xanthocephalus*), Red-winged (*Agelaius phoeniceus*) and Brewer's Blackbird (*Euphagus cyanocephalus*), Brown-headed Cowbird (*Molothrus ater*), and Savannah (*Passerculus sandwichensis*), and Vesper Sparrow (*Pooecetes gramineus*). No strychnine was detected in birds that were collected by various means outside the broadcast area. Horned Larks and Mourning Doves were most vulnerable, galliforms least vulnerable.

ACKNOWLEDGMENTS

We thank R. J. P. Meschishnick, D. and G. Wood for their observations on the rejection of viscera by hawks and owls. We are grateful to E. A. Driver, D. G. Forsyth, S. M. Schmutz and S. N. Wiemeyer for their helpful com-

ments on earlier versions of this manuscript. This work was supported by Environment Canada, the Special Areas Board of Hanna and the University of Saskatchewan.

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Received 12 April 1989; accepted 10 December 1989